FIFTEENTH SEMIANNUAL PROGRESS REPORT

January 1971

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MASSACHUSETTS INSTITUTE OF TECHNOLOGY
Center for Space Research

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For the Period

June 1, 1970 to November 30, 1970

on

NASA Grant NGL 22-009-019

To The

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

Office of University Affairs

FOREWORD

The following report summarizes the research carried out at the M.I.T. Center for Space Research under NASA Grant NGL 22-009-019 for the period June 1, 1970 to November 30, 1970.

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PHYSICAL SCIENCES AND ENGINEERING

STAR EVOLUTION STUDIES

Investigators: I. Iben, Jr., Z. Abraham, J. P. Huchra, R. T. Rood, W. D. Watson

Project No.: DSR 70469

Abraham has completed her work on solar models and is now writing the first half of her Ph.D. thesis. She concludes that a significant discrepancy still exists between theoretical unmixed solar models and the Davis neutrino result.

Rood is exploring the effect of mixing at the edge of the convective core in horizontal branch (HB) models; the dependence of HB luminosity on the mode of interpolating in the opacity; the dependence of HB color on the treatment of envelope convection; and the dependence of HB core mass on the initial composition.

Iben and Huchra have discovered, by analyzing results of linear pulsation calculations, a way of determining the transition period between pulsation at full amplitude in the first harmonic mode and pulsation at full amplitude in the fundamental mode. They find that a luminosity for RR Lyrae stars deduced by comparing with the observations on cluster variables is greater by about 0.25 magnitudes than predicted by Christy. There is now no conflict between luminosities deduced from evolutionary theory and those deduced with the help of pulsation theory. Iben is continuing with the pulsation work, finding, for example, that the transition edge defined by Christy is a function of the composition, contrary to Christy's claim.

Publications

1. Simoda, M. and I. Iben, Jr.: "Time-Constant Loci and Luminosity Functions for Metal-Deficient Clusters," Ap. J. Suppl. 22, No. 183, 81 (1970).

2. Watson, W. D.: "Element Diffusion and Abundance Anomalies in Metallic A Stars," Ap. J. 162, L45 (1970).

3. Rood, R. T.: "Models for Partially Mixed Stars," Ap. J. 162, 939 (1970).

4. Iben, I., Jr. and J. Huchra: "On the Helium Abundance in the Envelopes of the Bluest RR Lyrae Stars in Globular Clusters," Ap. J. 162, L43 (1970).

5. Abraham, Z. and I. Iben, Jr.: "The Abundances of He^3 and He^4 in the Initial Sun Implied by the Kocharov and Starburnov Assumption," Ap. J. 162, L125 (1970).

6. Iben, I., Jr.: "On the Role of the Computer in Astrophysics," chapter in book edited by A. Taub and Fernbach, Gordon and Breach, publishers (1970).

Submitted for Publication

7. Iben, I., Jr.: "On the Specification of the Blue Edge of the Instability Strip for RR Lyrae Stars," Ap. J.

8. Iben, I., Jr. and J. Huchra: "On the Blue Edge of the Instability Strip for Halo Population Variables," European J. Ast. and Ap.

TOPICS IN THEORETICAL ASTRONOMY AND COSMOLOGY

Investigators: P. Morrison, L. Sartori, F. M. Flasar, M. Kafatos, S. O'Dell

Project No.: DSR 70474

I. Spinars

An account of the evolution and nature of spinars is in press in the forthcoming volume which reports the proceedings of the Vatican Study Week on Active Galactic Nuclei, Rome, April 1970. This book should appear in the summer of 1971.

A paper, done with A. Cavaliere of M.I.T. and F. Pacini of Cornell[2], details a model for the emissions from a typical strong compact radio source. Using the spinar picture, a consistent set of parameters was presented describing the energy, lifetime, variations and spectrum of a quasar all the way from the meter band to the x-ray region.

Work is in progress on a derivation of the form of the particle energy spectrum, on an account of the time evolution of source density, and on other topics of spinar physics (P. Morrison and A. Cavaliere). F. M. Flasar is continuing to develop the phenomena and the physics of spinar fission, with special reference to M87, and to the point radio sources within the Cygnus A radio clouds recently reported. Kent Wood, teaching assistant, has made progress in working out the statistics of QSS and QSO. He finds a sharp distinction which can be interpreted in terms of the fission behavior of spinars.

II. Synchronton Emission and the Crab Nebula

The cyclotron cut-off process found by L. Sartori and S. O'Dell, already applied to the quasars as indicated above, has been used by these to authors to elaborate a model for the radiations from the Crab pulsar. The paper has already appeared. They are now trying to complete a model of the radiations from the Crab Nebula itself, which they might be able to do without invoking a stage of post-acceleration.

III. Emission Regions Around Old Supernovae

Recent observations and an ingenious interpretation by Maran, Brandt and others, seems to point to the well-known Gum Nebula around the Vela pulsar as the first known case of the suddenly produced photo-ionized regions of great volume and low emission measure expected around supernovae on the fluorescence theory (L. Sartori and P. Morrison). M. Kafatos has prepared a short paper which confirms this identification and suggests a number of other classes of observation to find more. The paper is in process of submission.

IV. Are White Dwarfs Spinars, Too?

A student, E. Turner, is examining this neat problem.

Publications

1. Morrison, P.: "The Crab X-rays," Pub. Astr. Soc., Pac., May 1970.

2. Cavaliere, A., P. Morrison and F. Pacini: "An Emission Model for the Strong Compact Sources," Astrop. J. Letters, November 1970.

3. Morrison, P.: "Active Galactic Nuclei," Science Year (1971).

4. O'Dell, S. and L. Sartori: Ap. J. 161, L63 (1970).

5. O'Dell, S. and L. Sartori: "Low-Frequency Cutoffs in Synchrotron Spectra," Ap. J. 162, L37 (1970).

STELLAR THEORY

Investigators: W. K. Rose, R. L. Smith

Project No.: DSR 70475

The nova outburst has been studied by solving the full set of gas dynamic and heat transfer equations for a hot white dwarf model with a thermally unstable hydrogen burning shell. The energy equation was modified by introducing a multiplicative factor, α, in the heat source term of the energy equation:

$$\frac{dE}{dt} + \rho \frac{d}{dt}\left(\frac{1}{\rho}\right) = \alpha \left(\varepsilon - \frac{\partial L}{\partial m}\right)$$

The ejection of a shell of matter from the star and the accompanying outburst of radiation was computed for two values of the parameter α: $\alpha = 10$ and $\alpha = 3$.

The qualitative features of the computed light curve show good agreement with the observations of fast novae, i.e., a very rapid initial rise followed by a much slower rise to maximum. The maximum, $M = -14$, is about five magnitudes greater than the maxima observed in real novae. This is a consequence of the extreme rates of energy generation at the hydrogen burning shell which have been introduced by the use of values of α greater than 1. The decline from maximum light has not yet been followed.

A comparison of the computed surface velocity during shell ejection is made for the two values of α. With $\alpha = 10$, the velocity of the ejected shell is about 10,000 km/sec. The largest observed velocities for novae are 4000 km/sec. The qualitative difference between the two cases indicates that further study of the effect of this parameter is required.

A set of model red giant envelopes for a .85 $M_\odot$ star has been computed for use as initial models for the hydrodynamic study of planetary nebula ejection. The luminosities for this set of models range from 4000 $L_\odot$ to 15,000 $L_\odot$. These extreme stars are characterized by "flat" density distributions in their envelopes.

A preliminary hydrodynamical calculation with a 13,000 $L_\odot$ model has shown that the rapid introduction of 2×10^{45} ergs of thermal energy into the base of the envelope is sufficient to eject most

of the envelope from the star. Envelope ejection will next be studied at lower luminosities and, in particular, with regard to the thermal instability in the helium burning shell.

INTERFEROMETRIC SPECTROSCOPY OF PLANETARY ATMOSPHERE

Investigators: T. B. McCord, C. B. Pilcher

Project No.: DSR 70476

Since June 1, 1970, work has been proceeding on the digital data system and optical systems associated with the Fourier interferometer spectrometer in our possession. Mr. Carl Pilcher, a graduate student, has been supervising this work as part of his doctoral research. At present, the fore-optics are complete and the data system only needs about one month more work. The instrument will be tested first in our laboratory and then on the telescope at the M.I.T. Wallace Observatory. Following successful test, the instrument will be used on telescopes in California, Arizona, and Chile this spring. The first scheduled project is high resolution spectroscopy of small areas on the surface (clouds) of Jupiter (Mr. Pilcher's thesis topic).

PROBLEMS IN ASTROPHYSICS

Investigators: C. C. Lin, S. Feldman, C. Hunter, W. W. Shane, A. Toomre

Project No.: DSR 70477

There has been only limited activity on this program since June 1, 1970, for the funds were indeed carried over from the previous semiannual period. Dr. Whitney Shane completed his analysis of the observational data in the Scutum Arm and in nearby directions. His results will soon be published. In the meantime, he has returned to Leiden, The Netherlands.

A report was made by Lin at the General Assembly of the International Astronomical Union, Brighton, England. It summarized many years of research work in this subject. This report will be published in Highlights of Astronomy, 1970.

Dr. C. Yuan's work (jointly with K. Grossman) on the migration of stars has just been issued as a report by the Institute for Space Studies, NASA, New York City.

Publications

1. Hunter, C.: "Large-Scale Oscillations of Galaxies," IAU Symposium No. 38, The Spiral Structure of Our Galaxy, eds. W. Becker & G. Contopoulos, 326-330 (1970).

2. Hunter, C.: "Rotation and Angular Momentum of Galaxies," Ap. J. 162, 445-452 (1970).

3. Lin, C. C.: "Interpretation of Large-Scale Spiral Structure," IAU Symposium No. 38, 377-390 (1970).

4. Toomre, A.: "Spiral Waves Caused by a Passage of the LMC?," IAU Symposium No. 38, 334-335 (1970).

5. Yuan, C. and K. Grossman: "Tables of Plane Galactic Orbits with Spiral Field," Vol. IV, Institute for Space Studies, NASA Goddard Space Flight Center, New York (1970).

To be published

6. Hunter, C.: "The Disklike Riemann Ellipsoids"

7. Lin, C. C.: "Theory of Spiral Structure"

8. Shane, W. W.: "Neutral Hydrogen in the Scutum Arm" (Ph.D. Thesis)

PHOTO-ELECTRON AND AÜGER SPECTROSCOPY

Investigators: R. E. Ogilvie, H. Newborn, R. Cava

Project No.: DSR 70479

Introduction

For many years the concentric spherical deflection analyzer as described by Purcell[1] has been considered the best electrostatic analyzer known, the reduced dispersion being larger than either that of the concentric cylindrical deflection device or the parallel plate mirror analyzer. Furthermore, the spherical deflection system provides two-dimensional focusing as an additional advantage in devices using axially symmetric beams. Recently, Zashkvara[2] et al. have shown the cylindrical mirror analyzer used by Blauth[3] to have the unsuspected property that second order focusing occurs at an entrance angle of 42.3° and $E_o/eV = 1.3\ r_2/r_1$ where V is the potential difference between the two concentric cylinders of radius r_1 and r_2 and E_o is the energy of the electron. It has been shown by Hafner[4] et al. that the design by Zashkvara has an improvement in the resolving power over the spherical analyzer. This has been demonstrated by Ogilvie[5] in a system designed to fit into the scanning electron microscope. A similar system was built by Sar-el[6] who independently found the unsuspected focusing properties of the concentric cylinders.

The Electron Energy Analyzer

A new analyzer was designed, based on the one that we used in the scanning electron microscope. This new analyzer is 12" long and 9" in diameter. The unique feature of this system is the Al Kα x-ray source for producing the photo-electrons and Auger electrons.

Because of the difficulties with the high voltage supply and its late delivery, the x-ray source has not been put into operation. When this is done, it will be a simple matter to test the resolution of the analyzer since all of the necessary equipment has been installed.

References

1. Purcell, E. M.: Phys. Rev. 54, 818 (1938).

2. Zashkvara, V. V., M. I. Korsunski and O. S. Kosmacker: Soviet Phys. - Tech. Phys. 11, 96 (1966).

3. Blauth, E.: Z. Physik 147, 228 (1951).

4. Hafner, H., J. A. Simpson and C. E. Kuyatt: Rev. Sci. Instr. 39, 33 (1968).

5. Ogilvie, R. E., J. Adario and G. Sheldon: Proc. IV Natl. Conf. on Elec. Microanalysis, 63 (1969).

6. Sar-el, H. Z.: Rev. Sci. Instr. 38, 1210 (1967).

ANALYSIS OF REACTOR PHYSICS AND HEAT TRANSFER IN NUCLEAR ROCKET REACTORS

Investigators: E. A. Mason, K. F. Hansen, T. R. Simpson

Project No. DSR 70480

A method of optimizing the axial power profile of a solid-core nuclear rocket reactor has been developed. The power profile is very dependent upon the heat transfer correlation used to predict channel wall temperatures, especially in the reactor core inlet region. The optimum reactor core dimensions and Isp are insensitive to the form of the heat transfer correlation used.

Reactivity characteristics for such compact, high performance reactor cores have been calculated. The hydrogen in the reflector can contribute several times more reactivity worth than the hydrogen in the reactor core. The critical uranium concentration, total and specific hydrogen reactivity worths, and mean fissioning energy are all strongly correlated to the geometrical buckling. Several equations were derived relating hydrogen worth to geometrical buckling. The total reactivity worth of hydrogen in the reflector is linearly proportional to the average hydrogen concentration in the reflector. Power tilting and loss of reactivity by core thermal expansion and corrosion loss of carbon were calculated. These reactivity characteristics agree favorably with values in the literature cited for the Rover nuclear rocket reactors.

Publications

1. Simpson, T. R.: "Heat Transfer Optimization and Reactivity of Nuclear Rocket Reactors," Ph. D. Thesis (1970).

2. Simpson, T. R. and E. A. Mason: "Heat Transfer Optimization and Reactivity of Nuclear Rocket Reactors," Trans. Am. Nuc. Soc., 13, No. 2, 438 (1971).

COMBINED RADIATION AND CONDUCTION HEAT TRANSFER

Investigator: L. R. Glicksman

Project No.: DSR 70481

The purpose of this project is to investigate experimentally heat transfer by combined radiation, conduction and/or convection in an absorbing-emitting medium and to check the validity of simplified analytical models. Molten glass was chosen as the modeling fluid because its physical properties are relatively easy to model.

An approximate technique has been previously developed to predict the temperature profile and heat flux in a gray medium with arbitrary geometry in which emission from the wall is important. The technique has been extended to include non-gray media characterized by an optically thick region, an optically thin region and a gray region of intermediate optical thickness. Errors in the predicted temperature distribution near the boundaries of the medium were investigated.

The feasibility of the spectral scanning technique for measuring temperature distribution in absorbing media is under investigation. An estimate is being made of the accuracy of the technique when no knowledge is available concerning the temperature distribution.

To Be Published

1. Glicksman, L. R. and P. A. Sykes: "Use of the Rosseland Approximation for Nongray Media."

2. Chen, K. H. and L. R. Glicksman: "Measurement of the Thermal Conductivity of Glass at High Temperatures."

MECHANISM OF TRANSIENT NATURAL CONVECTION IN ROCKET PROPELLANT TANKS

Investigators: L. B. Evans, R. C. Reid, E. S. Matulevicius, P. C. Pan

Project No.: DSR 70482

This research program has been directed toward an improved quantitative understanding of the mechanisms of natural convection in an enclosed fluid. Two Sc. D. candidates under the project have completed their doctoral theses[1,2].

In a combined theoretical and experimental investigation, carried out by Mr. E. S. Matulevicius as his doctoral thesis[1], insight was gained regarding the fundamental mechanisms that govern thermal stratification in enclosed fluids subject to a uniform sidewall heating. The phenomena near the liquid surface were studied by the measurement of the transient temperature and velocity profiles in the liquid. A theoretical model was developed, which can be used to predict the axial temperature profile within the propellant storage tanks on large rocket vehicles.

In addition, a practically feasible means has been found[3] to reduce the severity of thermal stratification by redistributing the sidewall heat flux. Visual observation using dye tracers indicated that the reduction of the severity of thermal stratification is the result of the separation of the natural convection boundary layer along the sidewall. The phenomenon of separation of a natural convection boundary layer is not well understood and is possibly due to the instability developed in the natural convection.

In a theoretical investigation of the stability of natural convection carried out by Mr. P. C. Pan as his doctoral thesis[2,4], the system of a viscous fluid enclosed between two infinite vertical parallel plates at different temperatures was chosen because of its receptivity to analysis. The stability analysis made use of the small perturbation theory and formulated the linearized perturbation equations in terms of three complex variables: (1) the amplitude of the disturbance stream function, (2) the amplitude of the disturbance vorticity, and (3) the amplitude of the temperature perturbation. The resulting 12th

order eigenvalue problem was then solved by an exact numerical method on the IBM 360/65 digital computer. In general, the method appears to be rapid and highly accurate, and can be easily generalized to solve more complex stability problems. The digital computer program is sufficiently general to allow a variety of flow profiles and boundary conditions to be studied.

The laminar natural convection under consideration was found to be unstable with respect to the stationary disturbances. The resultant disturbed flow may be in the form of transverse multicellular secondary flows or multicellular tertiary flows, depending on the strength of the disturbances. Numerical solutions to determine the neutral stability curves, critical Grashof numbers, and critical wave numbers were computed for 30 different Prandtl numbers ranging from 10^{-4} to 10^{3}, and separately for Prandtl number equal to zero. In addition, the streamlines and isotherms of both the disturbance and the total disturbed flow were displayed for each Prandtl number at its corresponding critical state. All these theoretical predictions were in satisfactory agreement with the available experimental observations reported in the literature. Both the critical Grashof numbers and wave numbers are weak functions of the Prandtl number. The weakness of the Prandtl number dependence suggests that the buoyancy force plays a small role in the destabilization and the instability of such a flow is essentially mechanically driven. This interpretation was further substantiated when the physical mechanism of the instability of this flow was considered from an energy conversion relationship between the disturbances and the basic steady state laminar natural convection velocity and temperature fields.

References

1. Matulevicius, E. S.: "Thermal Stratification in Enclosed Fluids due to Natural Convection," Sc.D. Thesis (1970).

2. Pan, P. C.: "Stability of Natural Convection between Two Vertical, Parallel Plates at Different Temperatures," Sc.D. Thesis (1970).

3. Evans, L. B., E. S. Matulevicius, and P. C. Pan: "Reduction of Thermal Stratification by Nonuniform Heating," To be published in AIChE J.

4. Evans, L. B., R. C. Reid, K. A. Smith, J. J. Noble, and P. C. Pan: "Stability of Natural Convection between Two Vertical, Parallel Plates at Different Temperatures," To be sumitted to Internat. J. Heat Mass Transfer.

LABORATORY FOR SPACE EXPERIMENTS

Investigators: R. H. Baker, L. H. Bannister, J. H. Binsack, H. V. Bradt, H. S. Bridge, R. J. Butler, G. W. Clark, J. V. Harrington, R. W. Rasche, G. Simmons

Project No.: DSR 70484

This laboratory, as an integral part of the Center for Space Research, draws its principal support from program funds as indicated in the following status report. In addition, some support is provided from NGL 22-009-019 funding for exploratory research and special projects of general interest to the space program. A number of these projects were started initially under NsG-496 funding and have subsequently found direct support from program funds in the manner indicated.

X-ray Sounding Rocket (NSR 22-009-129)

The rotating modulation collimator experiment 4.279 is in the process of being refurbished for a flight in the early part of March 1971 on an Aerobee 170 rocket. Two thin titanium window x-ray detectors are being prepared to be incorporated into this payload to detect x-rays at the low end of the x-ray spectrum (0.2 to 1.5 keV). These thin window counters are multianode sealed detectors; one detector filled with argon/xenon and the other filled with neon. The interstellar low energy x-ray cut-off from the galactic center, if any, will be measured with these two counters.

The main objective of the upcoming rocket flight (March 1971) is to locate precisely the x-ray sources, 340-8 and 349+2, in the Sagittarius region of the galactic equator. The data and results of the rotating modulation collimator experiment, 4.279, can be found in the September issue (1970), PP L161, H. W. Schnopper, H. V. Bradt, et al.

Work has begun to develop a gas flow, thin window, x-ray detector system for an Aerobee rocket to be flown in the fall of 1971. Thin organic films are being used for the detector windows to obtain high x-ray transmission in the 44 Å region of the spectrum. The gas flow system will be designed to maintain a constant gas pressure in the detector to achieve constant gain and, therefore, a predicted resolution for the detector can be obtained.

Concentrators with a small field of view will be placed in front of each detector to focus low energy x-rays to the window area of the counter.

The objectives of this flight are to measure the low energy x-ray flux at high and low galactic latitudes and to determine an x-ray spectrum or change of spectrum if any.

Multicolor X-ray Observatory (OSO-H) (NAS 5-11082)

The testing of both the flight and prototype units is continuing in the environmental chambers at Goddard Space Flight Center. The flight unit has undergone initial calibration, and a final calibration will be performed prior to integration into the spacecraft at Ball Brothers Research Center in mid-March. The prototype is to be refurbished and will serve as a flight spare.

Program delays have caused the expected flight date to slip until the end of FY 71. Some of this additional time can be profitably used for additional calibration and experience with the flight unit as well as attending to some minor problems uncovered in the environmental tests.

Small Astronomy Satellite-C (NAS 5-11275)

The program to design, develop, launch, and operate a comprehensive x-ray observatory using the Small Astronomy Satellite-C has been substantially expanded during the past quarter.

A payload has been designed and a flight program based upon the payload design has been identified. A proposal package for a flight program has been submitted to NASA.

We anticipate some modifications to the proposed design which will substantially extend the low energy response of the x-ray observatory. Current efforts are related to the detailed design of these low energy extensions together with a continuing design of the total payload in as much detail as resources permit.

IMP H&J Plasma Experiment (NAS 5-11062)

The protoflight experiment has been fabricated and each of the subsystems has been individually tested by appropriate substitution in the engineering model experiment. Some of the subsystems have already been interfaced and tested. The last

remaining logic subsystem is now being interfaced and will be tested in February 1971.

The protoflight measurement chain has been tested and is ready to be interfaced with the balance of the system. The protoflight modulator has not been delivered yet; the subcontractor has promised delivery on March 15, 1971. Final assembly and testing of the completed experiment will commence upon delivery of this item.

Delivery of the instrument to Goddard Space Flight Center for qualification is scheduled for mid-May, 1971.

The ground support equipment is completed and waiting to be interfaced with the assembled experiment.

Assembly of the flight spare for the H mission is proceeding at a rate that will result in an August, 1971, delivery.

The H mission launch is presently scheduled for April, 1972.

The computer-designed printed circuit boards worked out very satisfactorily. There are some detail improvements that should be made in the technique; however, from the standpoint of correct translation from circuit drawing to printed circuit board, the process is excellent.

Lunar Surface Electrical Properties Experiment (NAS 9-10748)

The chief objectives of this experiment are to determine layering in the lunar subsurface and to search for the presence of water at depth. In addition, the electrical properties of the lunar material will be measured in situ. Under favorable conditions, it may be possible to obtain an independent estimate of the lunar thermal flux and an indication of the number and size of subsurface scattering bodies.

The concept of the experiment is fairly simple. Electromagnetic waves which travel from a single source to an observing point by two different paths will interfere with each other. In some cases, the interference is destructive; in others, constructive, with the result that a series of sharp peaks and nulls are found. In the case of a reflecting interface at depth, these interference patterns can be generated readily by moving the receiver away from the transmitter. The reflecting plan can be any interface at depth, across which there exists a large contrast in dielectric properties, electrical conductivity, or density. The

identification of a series of peaks and troughs leads to a positive determination of the depth to the interface.

Since the presence of even minute amounts of water in rocks changes the electrical conductivity by several orders of magnitude, any moisture present will be detected easily by this experiment. Thus upper bounds can be set on the amount of water in the lunar subsurface. The frequency range of the experiment has been selected to allow determination of layering over a range of depths from a few meters to a few kilometers. Accordingly, it may be possible to determine the thickness of the outer layer, commonly referred to as the regolith or the "gardened layer," in the vicinity of the landing site. Such layering could be detected by the expected change in dielectric properties and conductivity. This subsurface topographic information holds considerable implications for the history of the outer few kilometers of the moon.

The medium being probed must have low electromagnetic losses in order for this radio frequency interferometry sounding technique to be effective. Ice provides one of the few earth environments which meets this condition. It is highly resistive and the bottom offers a good contrast. For this reason, glaciers provide suitable sites to test the interferometry technique.

Two major field tests have been conducted. The first, over the 450 meter deep Gorner Glacier, gave conclusive proof that the method is able to determine the electrical properties of a dielectric medium in situ. Using a set of engineering breadboards, a series of field trials were made on the shallower, 150 meter deep, Athabasca Glacier. Although a complete interpretation of the results is not yet available, the experiment indicated that the technique will give the depth to a reflector in a geological environment which has low electromagnetic losses. The data gave reasonable agreement with the theoretical results produced so far.

WAVES, MHD DISCONTINUITIES AND TURBULENCE IN INTERPLANETARY PLASMA

Investigators: C. K. W. Tam, V. Yousefian

Project No.: DSR 70486

It has been suggested by Chapman (1919) and Gold (1955) that during the occurrence of a solar flare a large quantity of plasma would be injected into the interplanetary space. This causes the formation of an interplanetary shock wave which propagates outward from the sun. Direct observations by space probe and satellite detectors show that these flare-induced shocks have a transit time to 1 AU of the order of 50 to 70 hours. One rather surprising feature of these shocks is that the measured propagation speeds of the shocks at 1 AU were lower than the mean transit speed from the sun. This suggests a deceleration of the shocks in the interplanetary space. In the past, the propagation of interplanetary shock waves has been studied by Parker (1961) who used a blast wave solution, and by Hundhausen and Gentry (1969) who employed numerical techniques. We have recently found a suitable analytical method to investigate this problem. This method not only has the advantage of simplicity but also can be extended to account for the interplanetary magnetic field which has so far been neglected. Near the earth the interplanetary magnetic field pressure and plasma pressure are about equal. It is expected, therefore, that the effect of the magnetic field will strongly modify the propagation characteristics of the shock waves.

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1. Parker, E. N.: Astrophys. J. 133, 1041 (1961).

2. Hundhausen, A. J. and R. A. Gentry: J. Geophys. Res. 74, 2908 (1969).

SOCIAL SCIENCES

STUDIES OF THE IMPACT OF THE SPACE PROGRAM ON LOCAL, NATIONAL AND INTERNATIONAL AFFAIRS

Investigator: E. B. Skolnikoff

Project No.: DSR 70485

The analysis of the international political and institutional implications of new technology, partially supported with Space Center funds, has been completed and will appear as a book in 1971. Several papers have also resulted from the project and will appear in various publications and books in the next year.

Follow-on work is temporarily in abeyance since the chief investigator, Professor Skolnikoff, has assumed the duties of Chairman of the Political Science Department. Various detailed follow-on aspects of the overall project are being considered, however, as well as other space-related projects in the space communications area.

FORMATION AND GROWTH OF TECHNOLOGY-BASED ENTERPRISES

Investigator: E. B. Roberts

Project No.: DSR 76154

The final research carried out under the funding of NASA furthered earlier work on the financial markets affecting the founding of high technology companies. Russell Faucett's[1] studies of major venture capital organizations demonstrated that their performance has been enhanced primarily by investments in technical companies and at the startup (Stage I) phase. Related earlier studies contributed to the findings of the U. S. Department of Commerce Venture Capital Panel, of which Professor Roberts was a member, recently released in their report[2].

In seeking to communicate the results of the research project to date, additional journal articles have been prepared[3,4] and presentations made to a large number of university, industry and governmental groups, including conferences of the Innovation Group and the Symposium on New Enterprises at Purdue University.

Publications

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LIFE SCIENCES

VAPOR-LIQUID EQUILIBRIA OF VOLTATILE ORGANIC SOLUTES

Investigators: P. Issenberg, C. Y. Hwang

Project No.: DSR 70473

The relative contributions of sorption and diffusion in retention of volatile organic compounds during drying and long term storage of foods and other biological materials depends on composition of the system and on drying conditions. Most previous investigators have studied diffusion rates under experimental conditions which minimize adsorption. The primary objective of the present studies is evaluation of the role of adsorption of volatile compounds in systems containing solids typical of those found in foods.

During the course of sorption measurements with the frontal analysis gas chromatographic system, inconsistencies were observed which were tentatively attributed to variations in surface area of the sorbents employed. Some preliminary estimates of surface area of microcrystalline cellulose indicated that column packing procedure could influence surface area as measured by nitrogen sorption. These surface area differences resulted in inability to reproduce sorption isotherms for organic sorbates when columns containing different amounts of sorbent were employed.

The frontal analysis apparatus has been modified for measurement of surface areas by the nitrogen adsorption method. A thermal conductivity detector was incorporated and a system for preparing mixtures of nitrogen and helium was added. Columns are similar to those previously employed, but are packed more loosely to minimize pressure drop. Measurements can be made during either adsorption or desorption of nitrogen from the nitrogen-helium mixtures. The column is cooled to -196° C for adsorption and heated to room temperature to accelerate desorption. The surface area of a potato starch sample, as measured by conventional B.E.T. treatment of the nitrogen sorption data, was 83.6 m^2/g. The B.E.T. plot was linear for relative pressures of nitrogen in the range of 0.02 to 0.2. The method and apparatus are being used to measure surface areas of a variety of food components including starch, cellulose, glucose and casein prior to use of these materials in studies of sorption of volatile organic compounds.

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THESES

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Faucett, Russell B.	The Management of Venture Capital Investment Companies	S.M. 1971	Management
Pan, Peter C.	Stability of Natural Convection between Two Vertical Parallel Plates at Different Temperatures	Sc.D. 1970	Chemical Engineering
Shane, William W.	Neutral Hydrogen in the Scutum Area	Ph.D. 1970	Mathematics
Simpson, Terry R.	Heat Transfer for Optimization and Reactivity of Nuclear Rocket Reactors	Ph.D. 1970	Nuclear Engineering